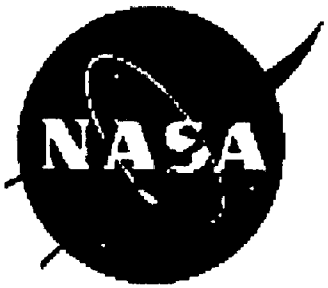


Effects of AEA Cell-Bypass-Switch Closure on Charged EOS-Aqua NiH_2 Cell

2000 NASA Aerospace Battery Workshop

Denney Keys
Gopalakrishna M. Rao
David Sullivan
Harry Wannemacher*

NASA GODDARD SPACE FLIGHT CENTER
*QSS GROUP, INC

Objectives

- Verify the Performance of AEA Cell Bypass Protection Device (CBPD) under simulated EOS- Aqua/Aura flight hardware configuration
- Assess the Safety of the hardware under an inadvertent firing of CBPD switch, as well as the closing of CBPD switch under simulated high cell impedance
- Confirm that the mode of operation of CBPD switch is the formation of a continuous low impedance path - homogeneous low melting point eutectic (Indium alloy)

EOS-Aqua Flight Hardware

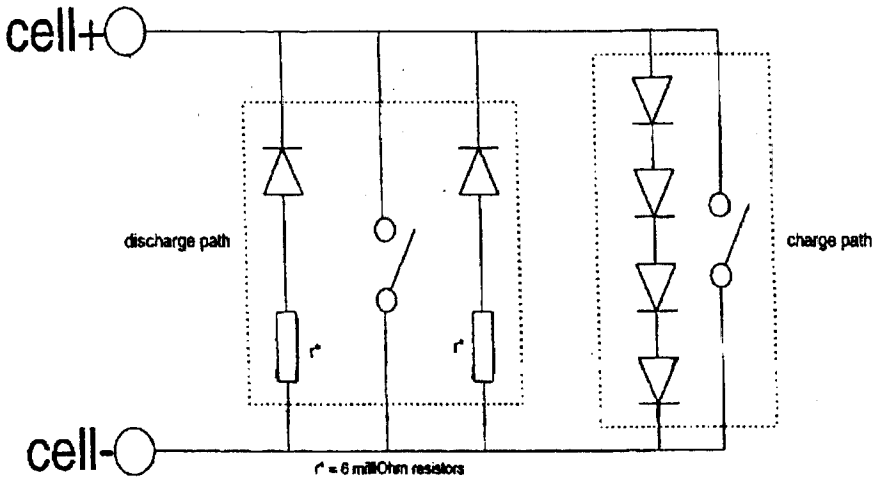
- Battery Cells:
  - Eagle-Picher 160 Ah NiH_2 (RNH 160-3)
  - Size: ~ 12cm Diameter
    ~ 32cm overall Height
  - Weight: ~ 4.3kg
- Cell-Bypass-Switch:
  - AEA Technology
    Cell Bypass Protection Device (CBPD)
    P/N: 1Z019-001S-001

AEA Hardware Tested

- A total of five (5) CBPDs were tested using the charged EOS Cell
  - Three FLIGHT devices (F01, F02 and F03)
  - Two ENGINEERING MODEL devices (EM01 & EM02)
- The two types of CBPDs are basically the same, with a change in separator and minor outer dimension changes

AEA Bypass Switch Schematic

CBPD - LMPA Schematic
(Low Melting Point Alloy)



AEA Technology

Slide serial no 6

NOTE: Tested devices have 6 series diodes in charge path (not 4 as shown)

FLIGHT CBPD

AEA Cell-Bypass-Switch Spec

CBPD - Specification

- 75grams
- Icharge < 35A
- I discharge < 235A
- Triggering - see operation summary
- R ~ 200 microOhms
- I operation < 400A - dependent on leads and mounting

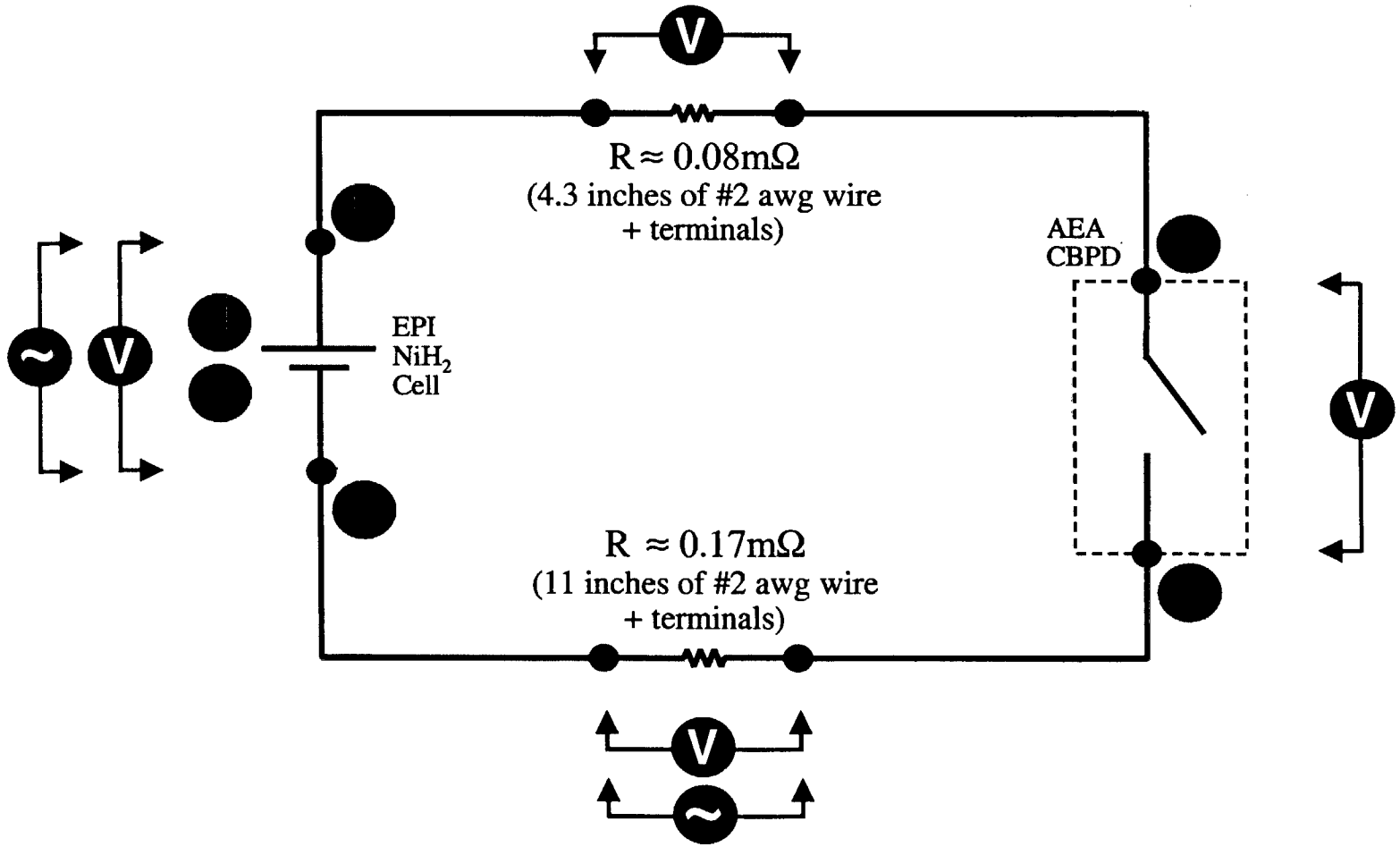
AEA Technology

Slide serial no 13

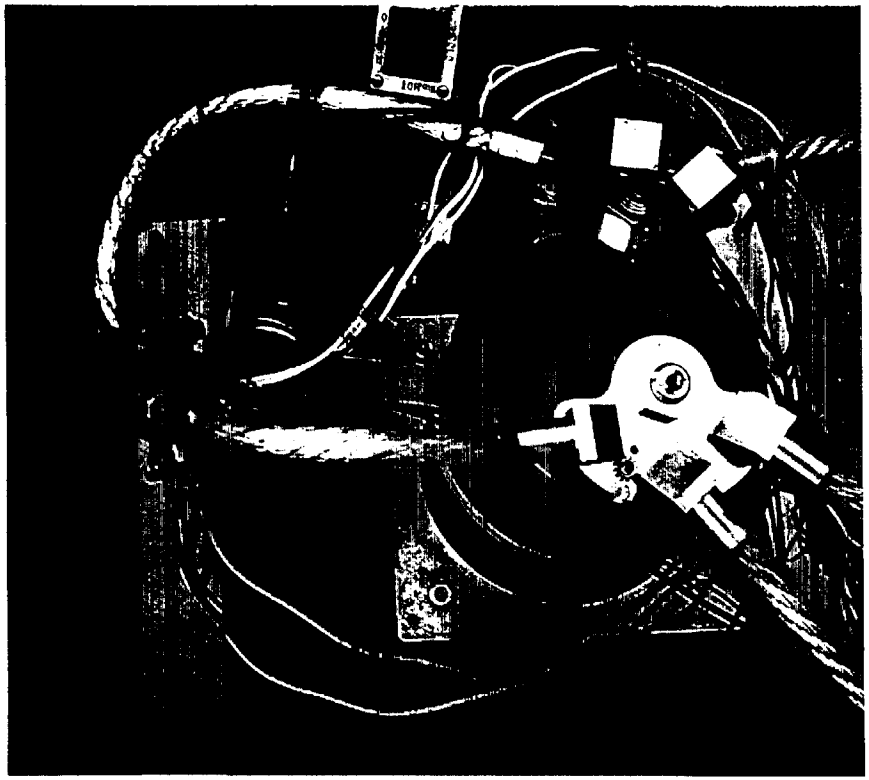
Tests Performed

- Test#1: CBPD F01
  Activated with heatgun
  Long-axis ~30° from Horizontal
- Tests #2 & 3: CBPD EM01 & EM02
  Activated through charge diodes
  Long-axis Horizontal
- Test#4: CBPD F02
  Activated through charge diodes
  Long-axis Vertical (launch orientation)
- Test#5: CBPD F03
  same as Test#4, with added 50 mΩ resistance in current path

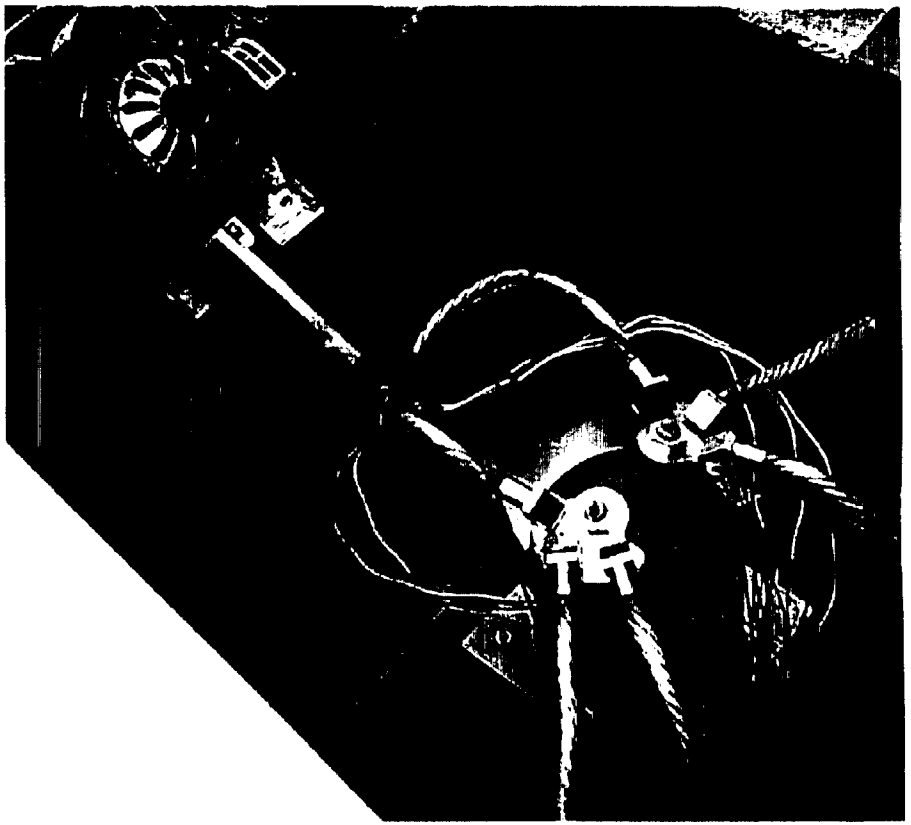
Test #1 setup (switch activated with heatgun)



Test #1 (F01)

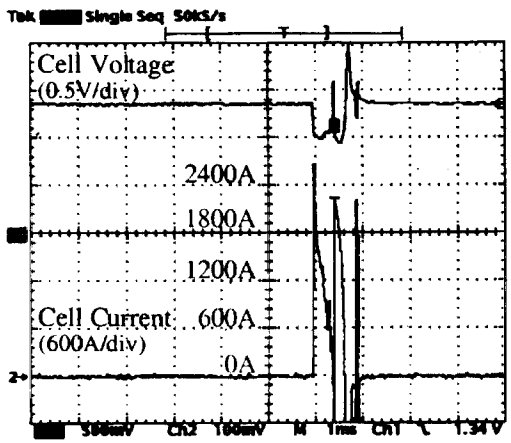


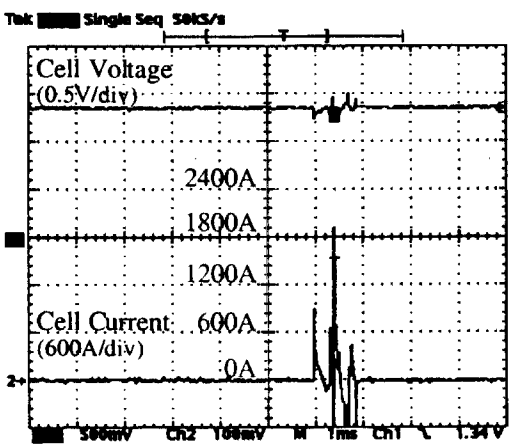
First application of heatgun

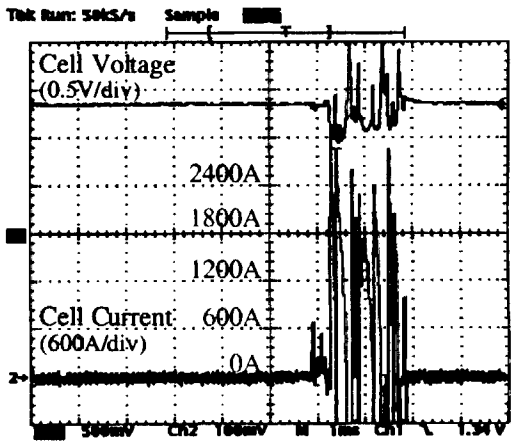


Heatgun repositioned for second application

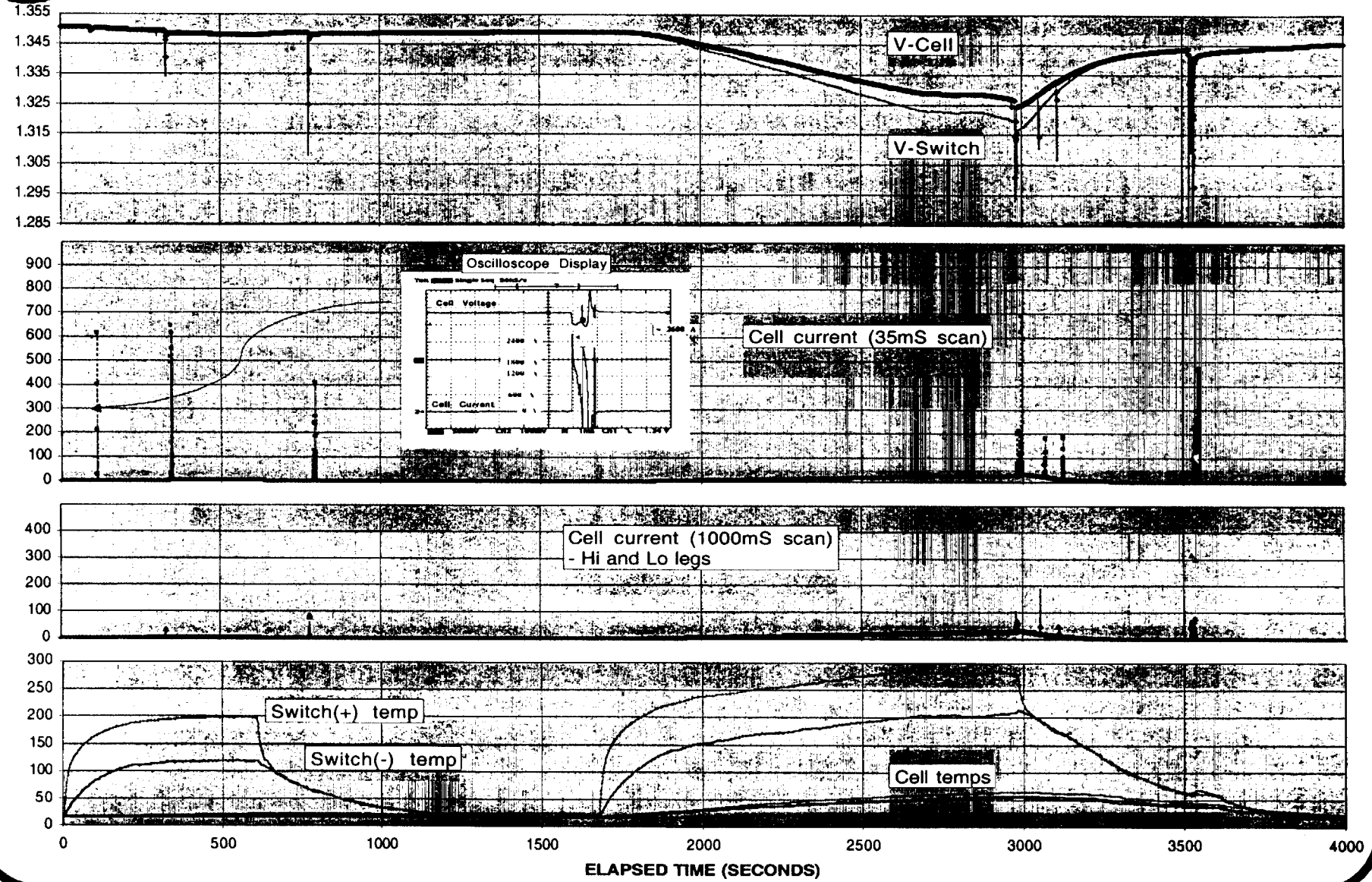
Test #1 Scope Traces



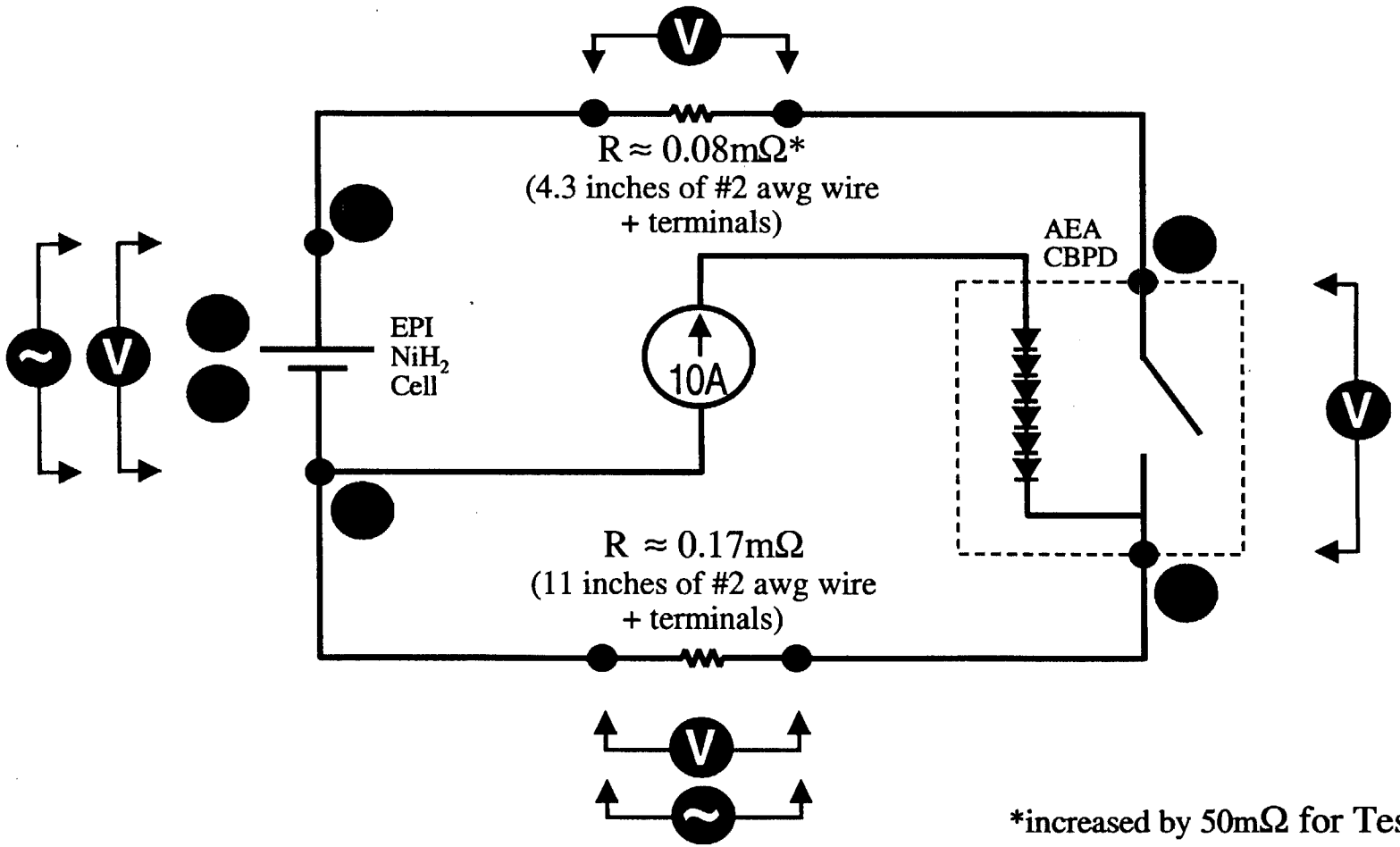




Test #1 Data

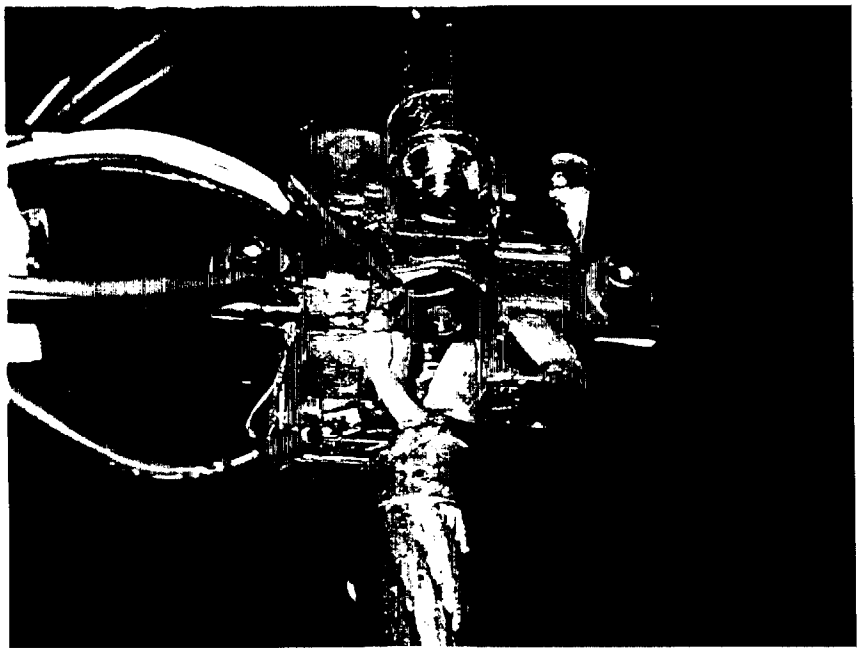

1.355
1.345
1.335
1.325
1.315
1.305
1.295
1.285
V-Cell
V-Switch
900
800
700
600
500
400
300
200
100
0
Oscilloscope Display
Cell Voltage
Cell Current
Cell current (35mS scan)
400
300
200
100
0
Cell current (1000mS scan)
- Hi and Lo legs
300
250
200
150
100
50
0
Switch(+) temp
Switch(-) temp
Cell temps
0
500
1000
1500
2000
2500
3000
3500
4000
ELAPSED TIME (SECONDS)

Test #2 thru 5 setup (switch activated through diodes)

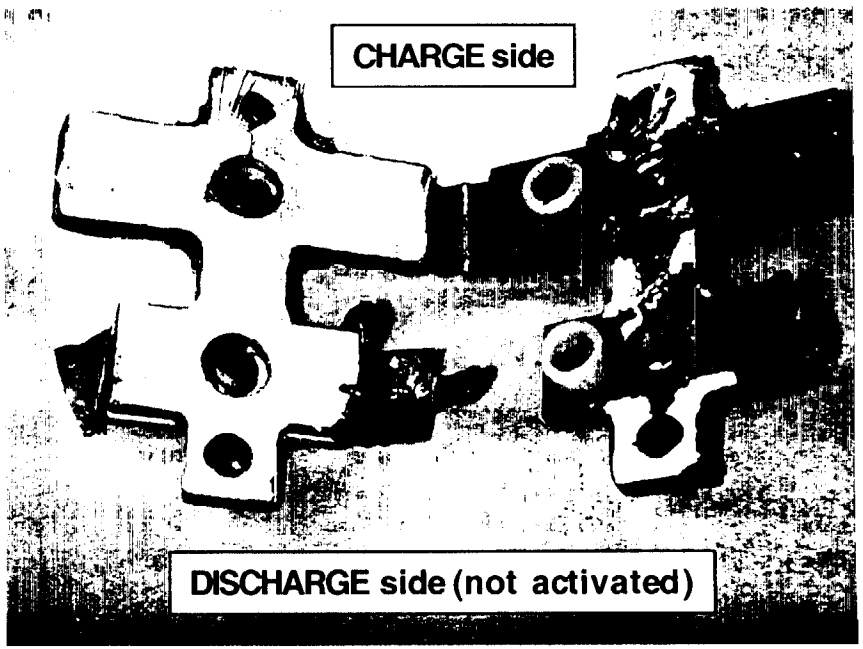


*increased by 50mΩ for Test #5

Test #2 (EM01)

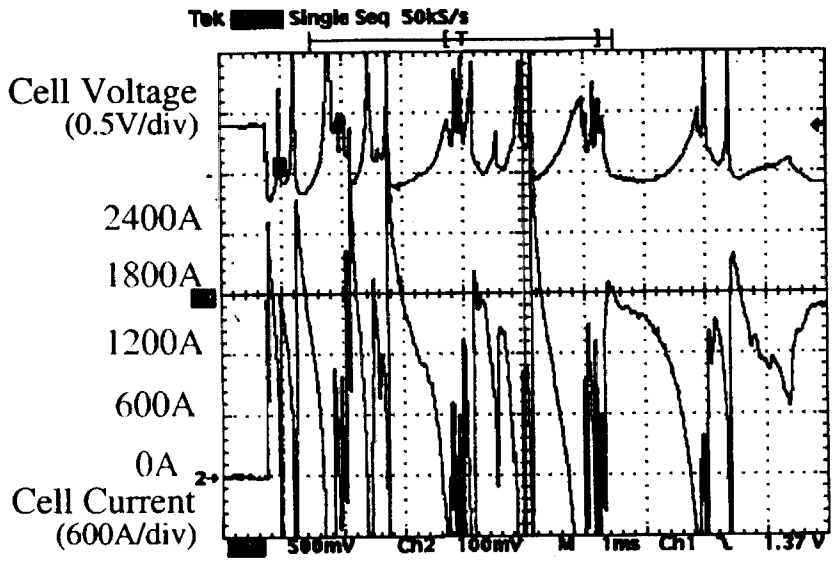


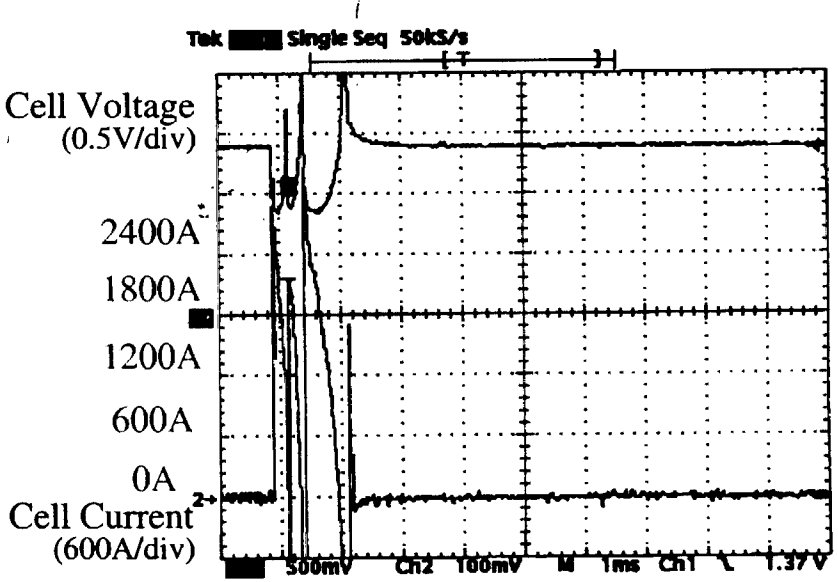
Engineering Model CBPD
after test



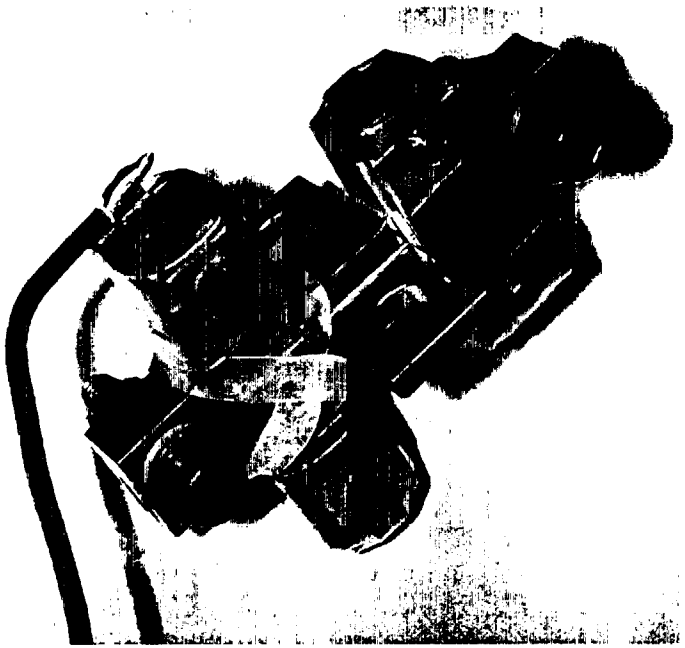
CBPD opened after test.

Test #2 & 3 Scope Traces

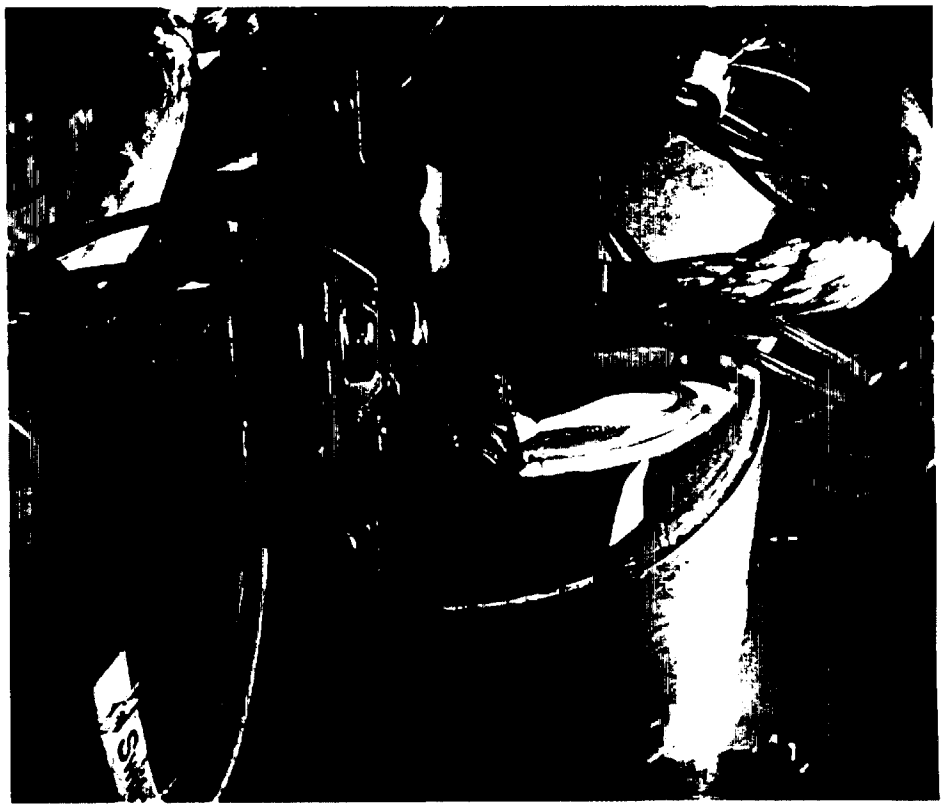




Test #4 (F02)

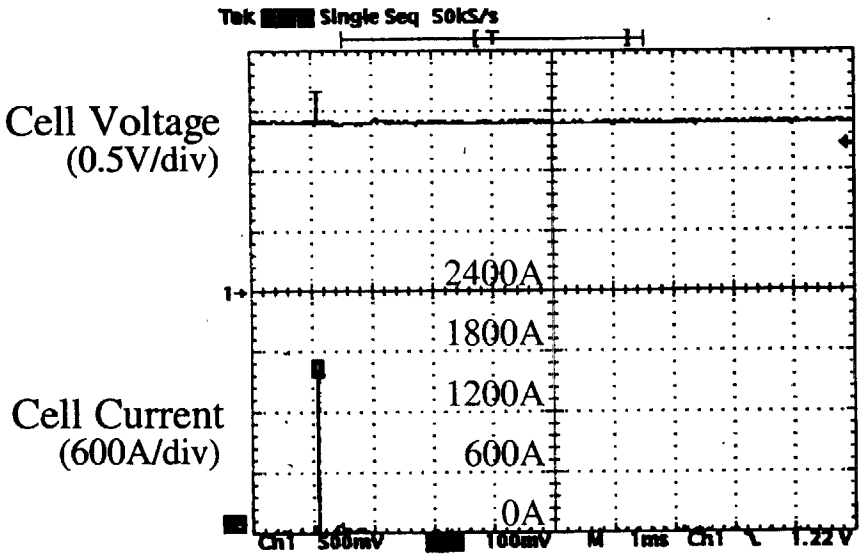


Charge diode string connection

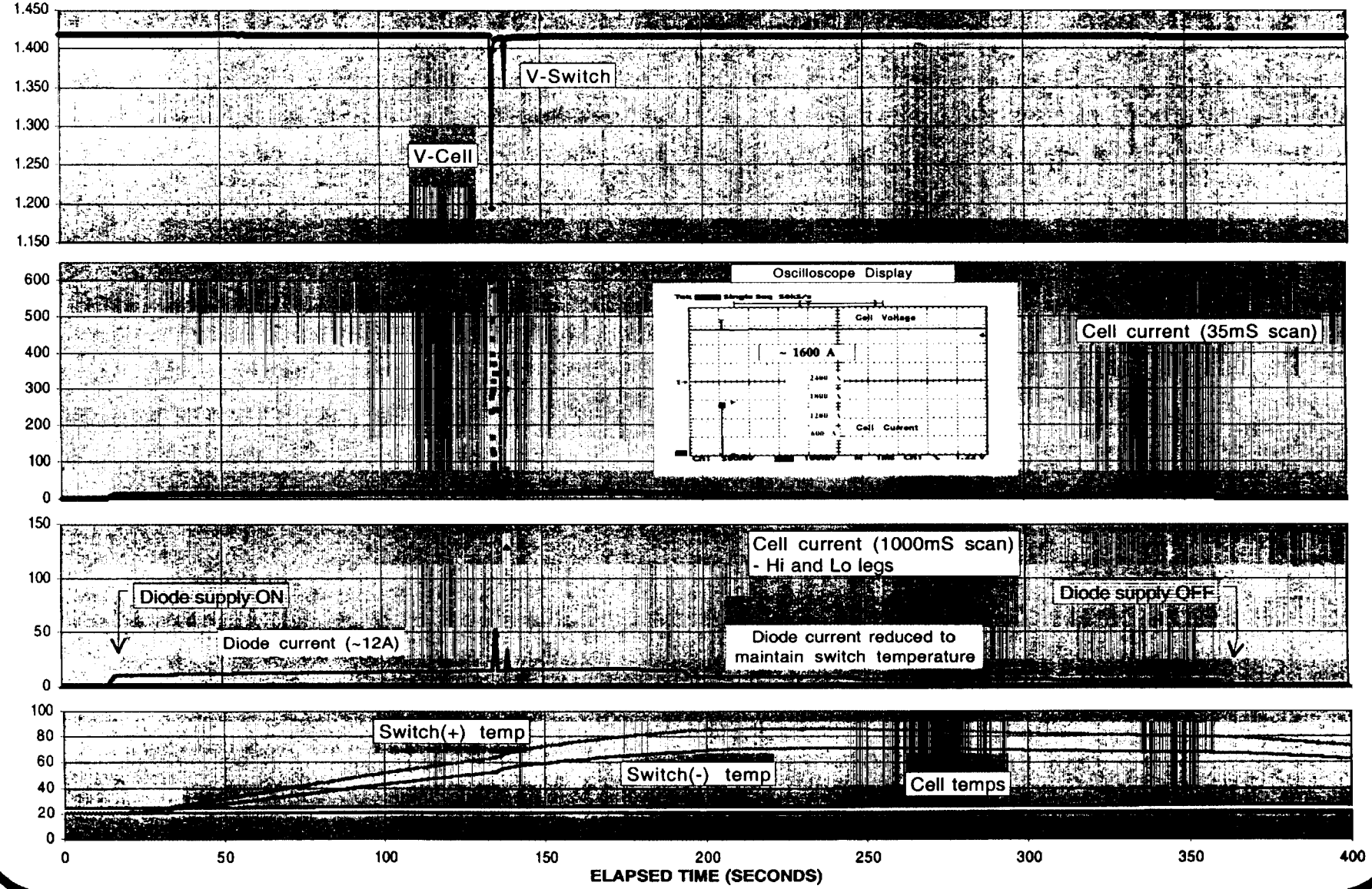


CBPD in launch orientation.

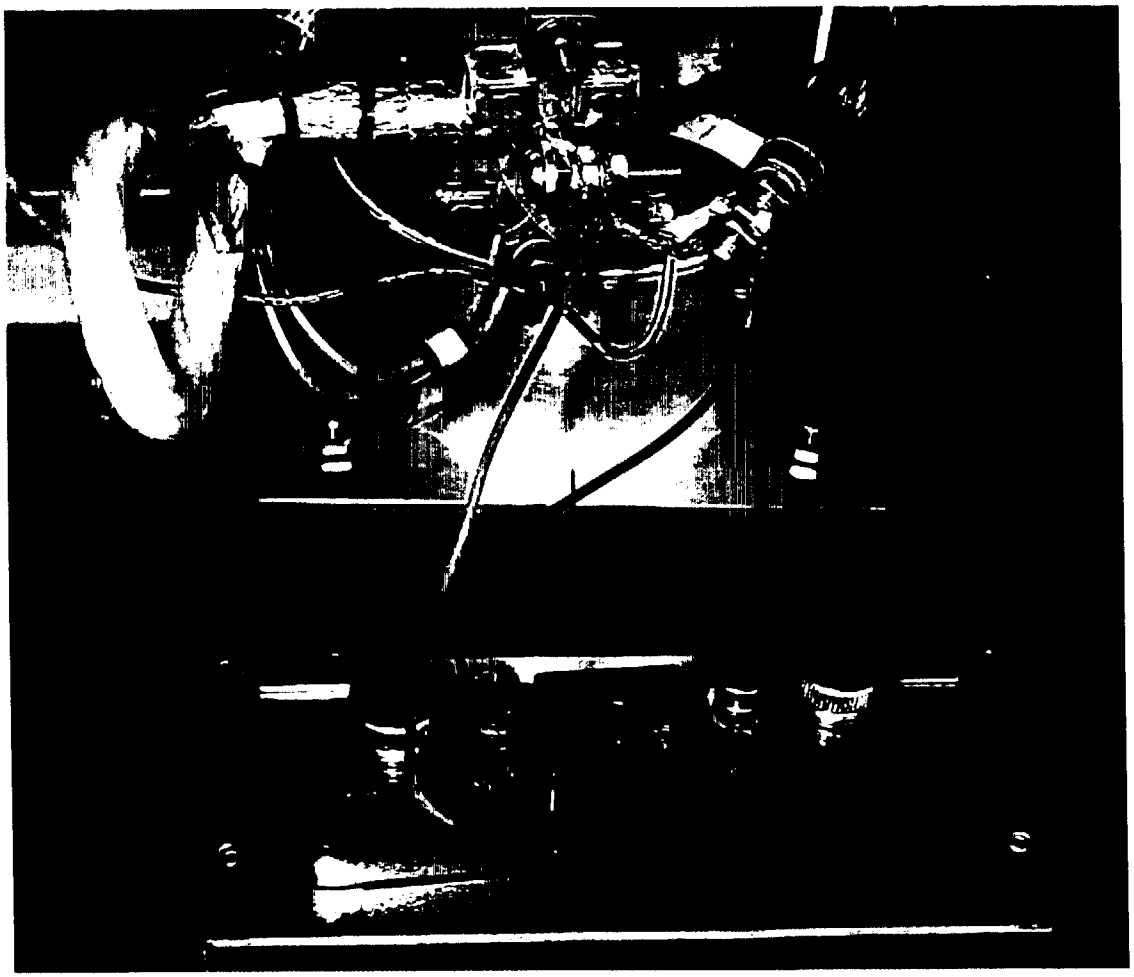
Test #4 Scope Trace



Test #4 Data

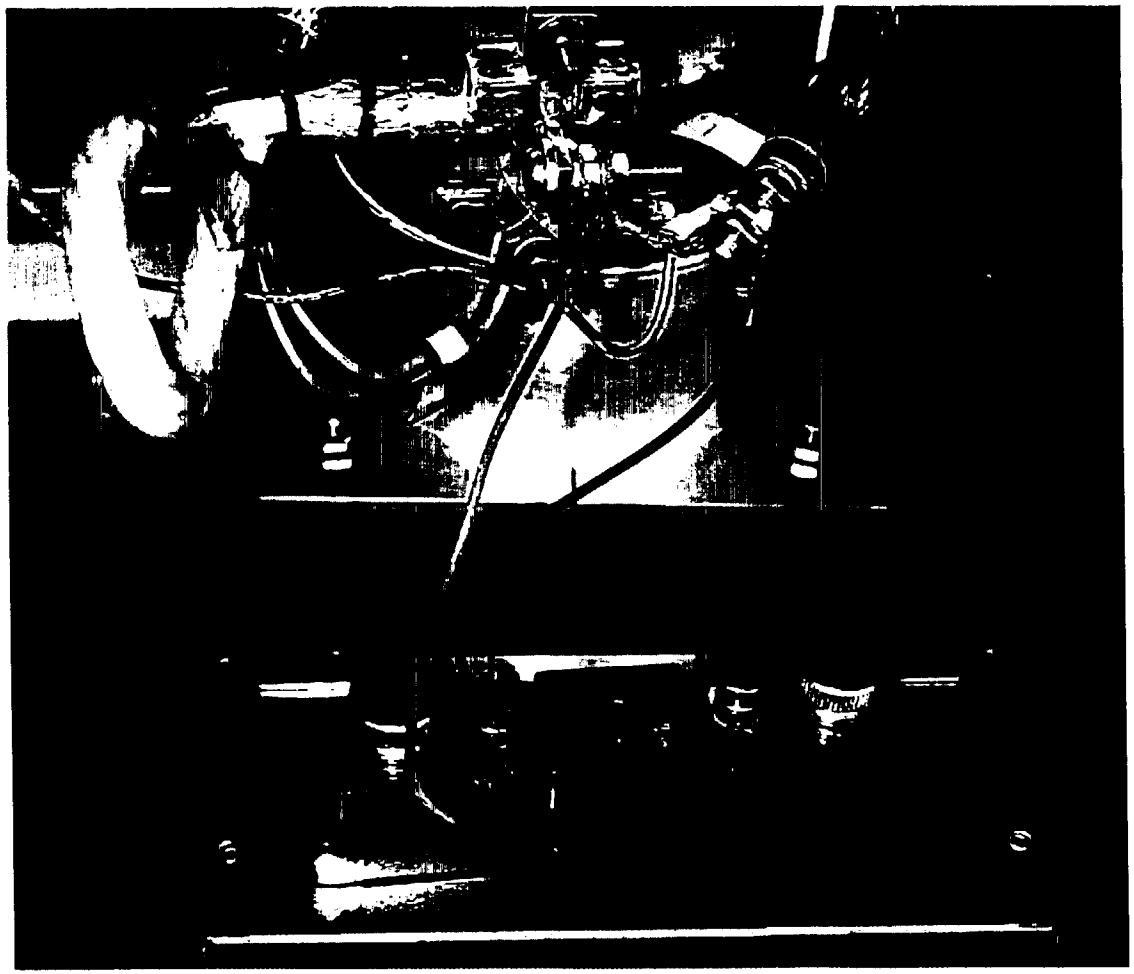

1.450
1.400
1.350
1.300
1.250
1.200
1.150
V-Switch
V-Cell
600
500
400
300
200
100
0
Oscilloscope Display
Cell Voltage
~ 1600 A
Cell Current
Cell current (35mS scan)
150
100
50
0
Cell current (1000mS scan)
- Hi and Lo legs
Diode supply ON
Diode current (~12A)
Diode current reduced to
maintain switch temperature
Diode supply OFF
100
80
60
40
20
0
Switch(+) temp
Switch(-) temp
Cell temps
0
50
100
150
200
250
300
350
400
ELAPSED TIME (SECONDS)

Test #5 (F03)



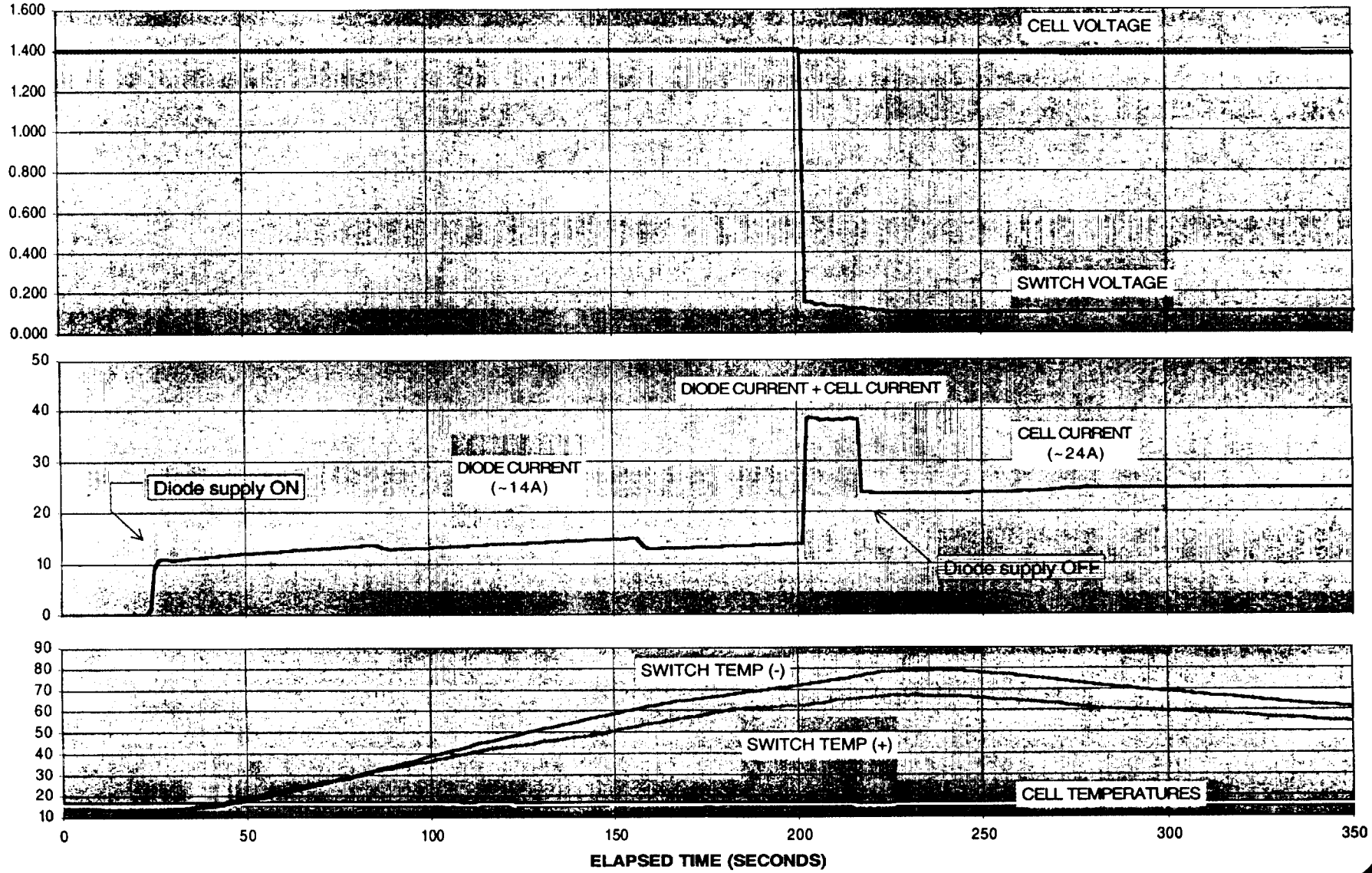
50 mΩ resistance added to positive current path

Test #5 (F03)

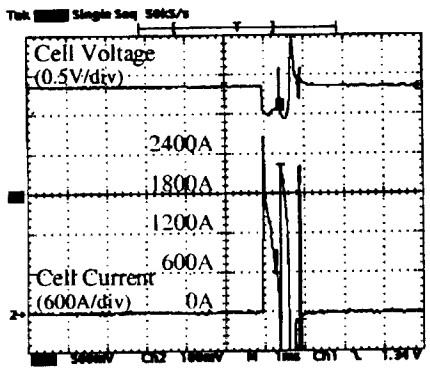


50 mΩ resistance added to positive current path

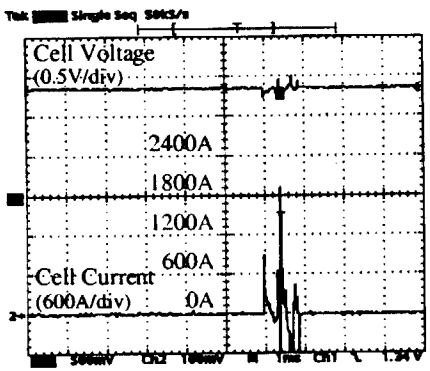
Test #5 Data (with added 50mΩ)



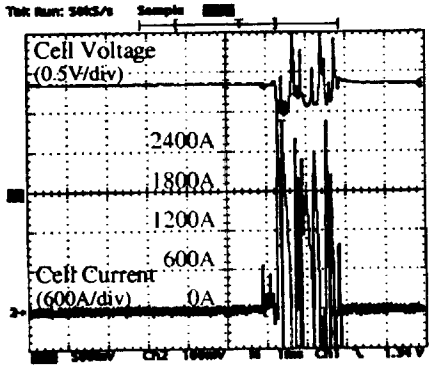
Scope traces for Tests #1 thru 4



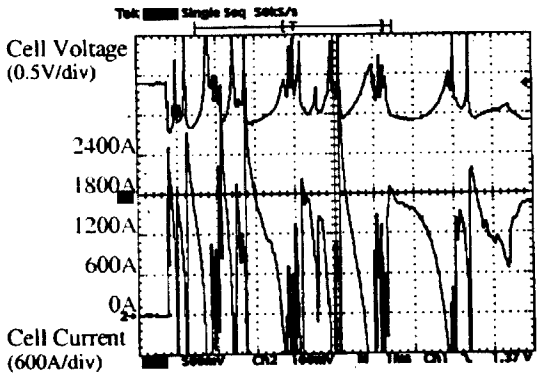
Test #1 (F01)



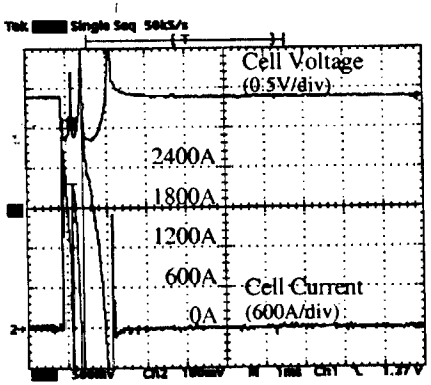
Test #1 (F01)



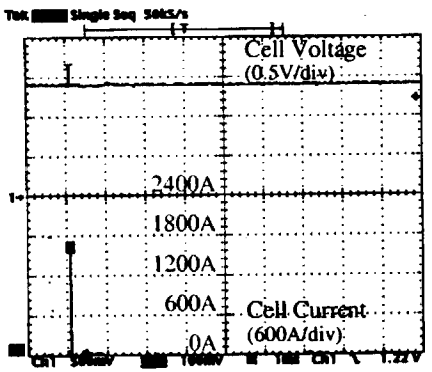
Test #1 (F01)



Test #2 (EM01)



Test #3 (EM02)



Test #4 (F02)

Test Summary

Test #	CBPD #	Result
1	F01	- Seven distinct current bursts were recorded - Switch failed to provide continuous short even after heating to near 300°C - It is expected that both charge and discharge switches were activated by the high temperature
2	EM01	- One distinct current burst was recorded - Switch failed to provide continuous short
3	EM02	- One distinct current burst was recorded - Switch failed to provide continuous short
4	F02	- One distinct current burst was recorded - Switch temperature was maintained over three minutes past the event, and switch still failed to provide continuous short
5	F03	- With 50mΩ added to the current path, switch closed as expected, and maintained low impedance after diode current was removed and switch cooled

Conclusions

- The nominal performance of AEA CBPD under simulated EOS-Aqua/Aura flight hardware configuration has been demonstrated.
- There is no evidence for cell rupture or excessive heat production during or after CBPD switch activation under simulated high cell impedance (open-circuit cell failure mode).
- Inadvertent CBPD switch activation with a charged cell (low impedance path) intermittently closes and opens up the switch, therefore the device may or may not provide protection against future open-circuit cell failure.
  Further testing with switch F02 may provide clarification.
- The formation of a continuous low impedance path, i.e. a homogeneous low melting point eutectic (Indium alloy), has been confirmed - which is the expected mode of operation.